CDF Run 2 EndPlug Calorimeter Upgrade

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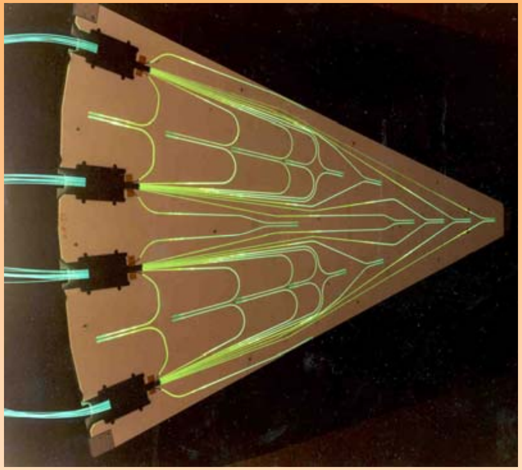


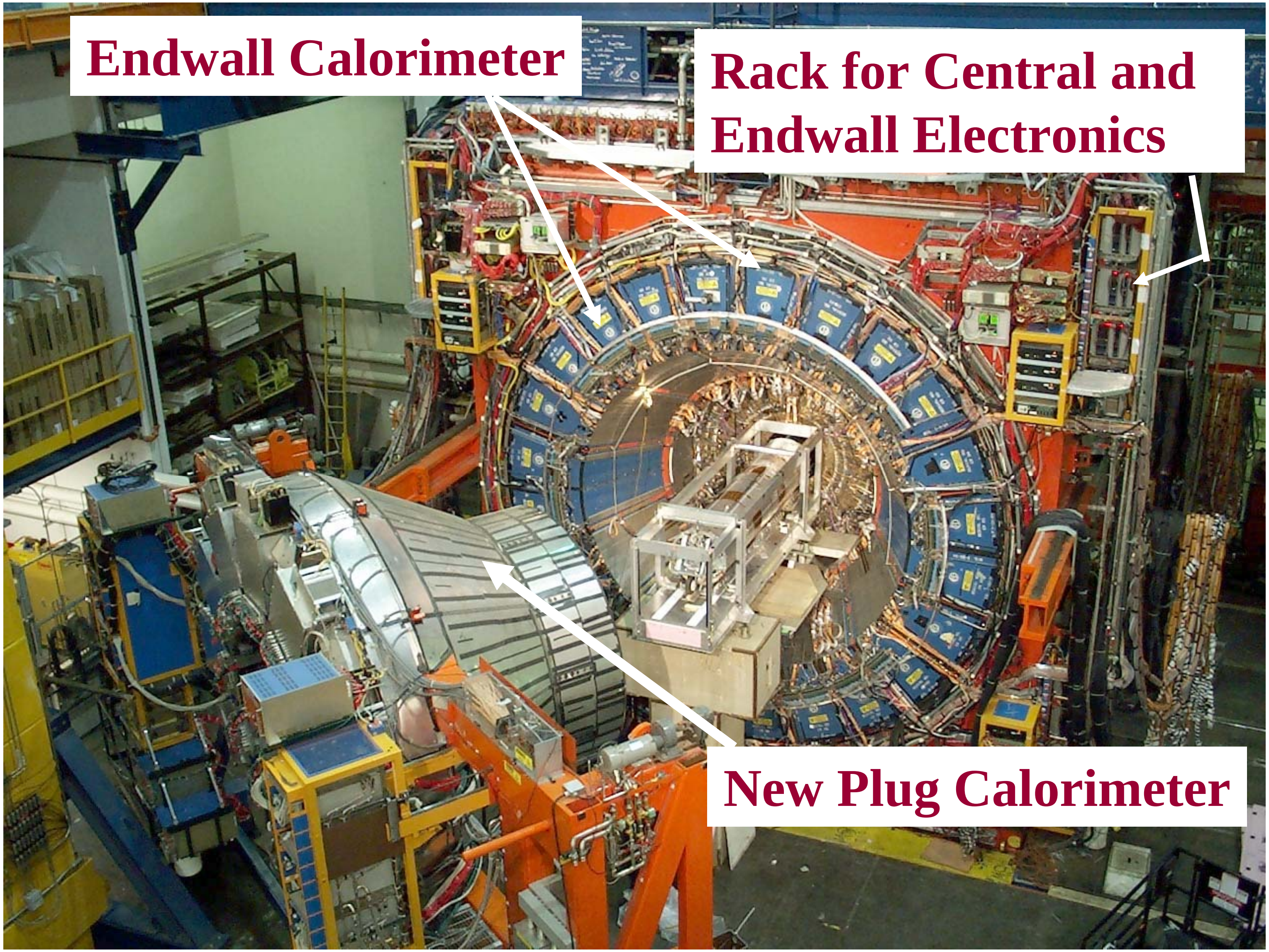
Muon WG, ALCPG & ILC Snowmass -- Tuesday August 23, 2005

A Funny Thing Happened on the Way to Snowmass…

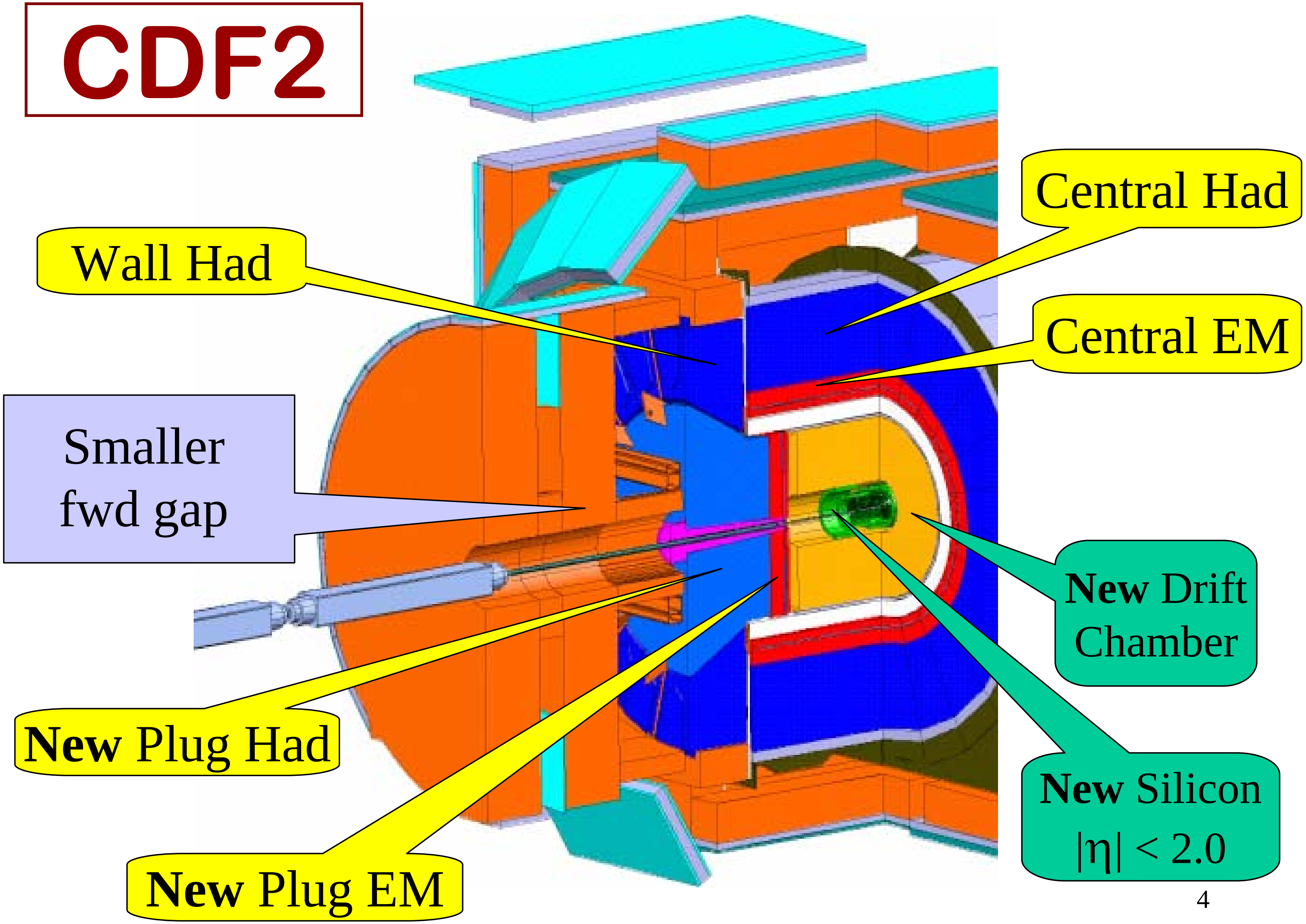
Contacted by Paul Karchin: looking for CDF calorimeter experts to discuss wavelength-shifting fiber (WLS) and multi-anode PMT technology as used by CDF.

- Only three CDF "calorimeter people" registered…
- Best person to give these talks: Steve Kuhlmann (only here 3 days last week)
- Robin Erbacher: Best person to discuss this for the calorimeter endplug upgrade (though readout expert)
- Gianluca Introzzi: Best person present to discuss this for the more recent Central Preradiator (CPR) Upgrade

The CDF2 Calorimeter System



CDF2

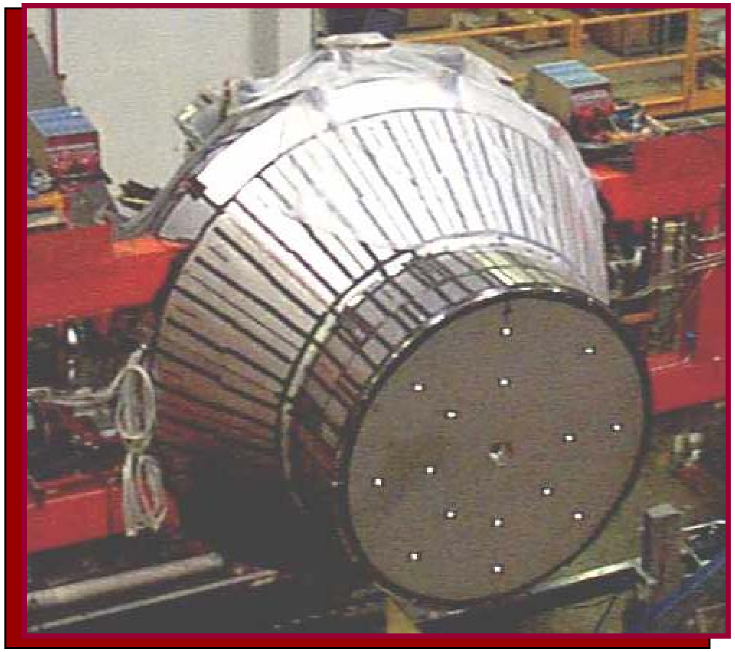


Central Had
Wall Had
Central EM
Smaller fwd gap
New Drift Chamber
New Plug Had
New Silicon $|\eta| < 2.0$
New Plug EM

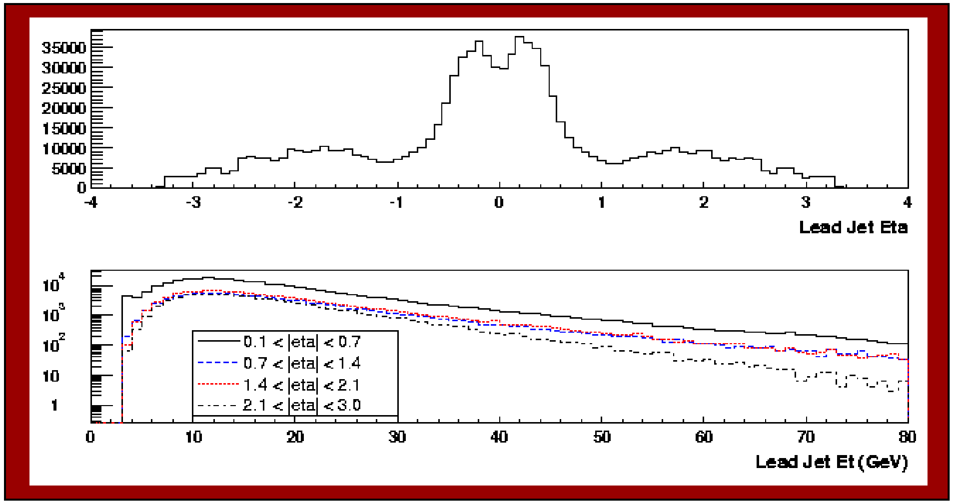
Calorimeter Integration

- **Various Tevatron upgrades required changes to system, enabling integration:**
  - $\sqrt{s}$: 1.8 → 1.96 TeV (PMT signals double)
  - Bunch Xing: 3.5 μs → 132 ns (new FEE/trigger)
  - Lum: 2x10^{31} cm^{-2}s^{-1} ('96) → 5x10^{32} (>'04)
- **Replacement of old gas plug calorimeters**
  - Rate limitations at Tevatron Run 2
  - Forward noisy due to insufficient shielding
  - Unlike in the central, no EM pre-shower and no timing measurement.

EndPlug Upgrade



- **New Plug Calorimeters**
  - Scintillator tile design: Fast ! plus better sampling fraction than Run I gas detector
  - Same technology over full solid angle to $|\eta| = 3.6$
  - More hermetic: 10^o fwd gap gone, 30^o reduced



- **Central Calorimeters**
  - Kept Run I detectors
  - Scintillator based→fast
  - New readout electronics

EndPlug Project History

- Started in ‘91-’92 with Test Beam studies on an engineering prototype (technology here ~decade old!).

- Detector production took place in ‘93-’96.

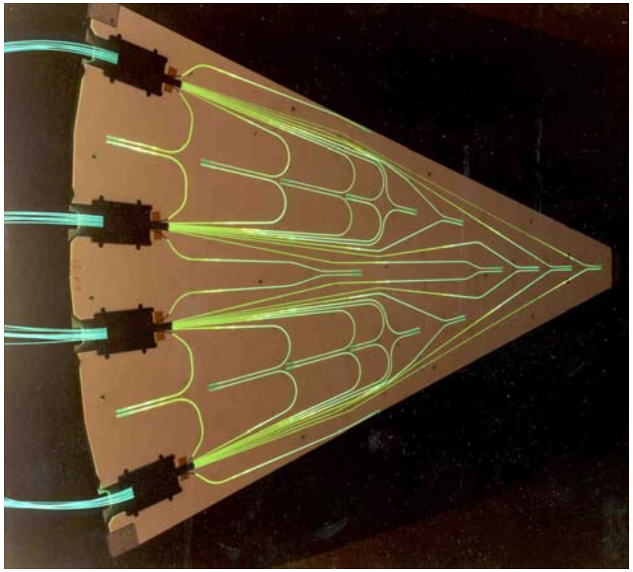
- Mechanical structure assembly happened in ‘96-’97. During ‘97 focus on detector assembly and performance understanding.

- Detector Installation begins July 97.

- Plug basically ready for 2000 Commissioning Run.

- Endplug preradiator, EM, HAD, and shower max fully functional in CDF data-taking now.

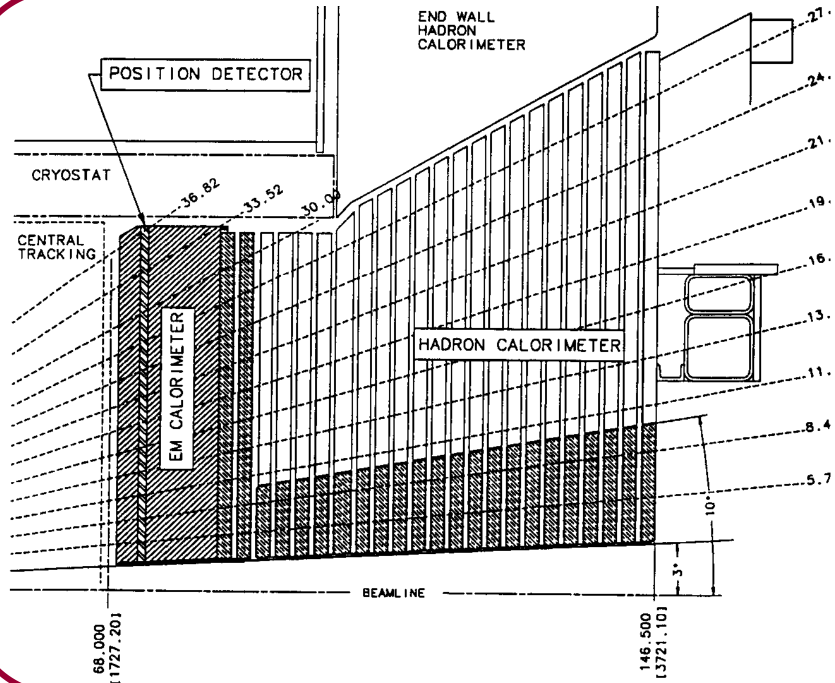
Similar Technology Across η



- **All calorimeters now use scintillators plus WLS:**
  - **Central: plastic slab with lead/steel and WLS**
  - **Plug: scintillator tile with lead/steel and WLS**

SEGMENTATION OF THE "PROJECTIVE" TOWERS

$\lvert\eta\rvert$ range	$\Delta\phi$ size	$\Delta\eta$ Size
0.-1.2	15°	0.1
1.2-1.8	7.5°	0.1
1.8-2.1	7.5°	0.16
2.1-3.6	15°	0.2-0.6

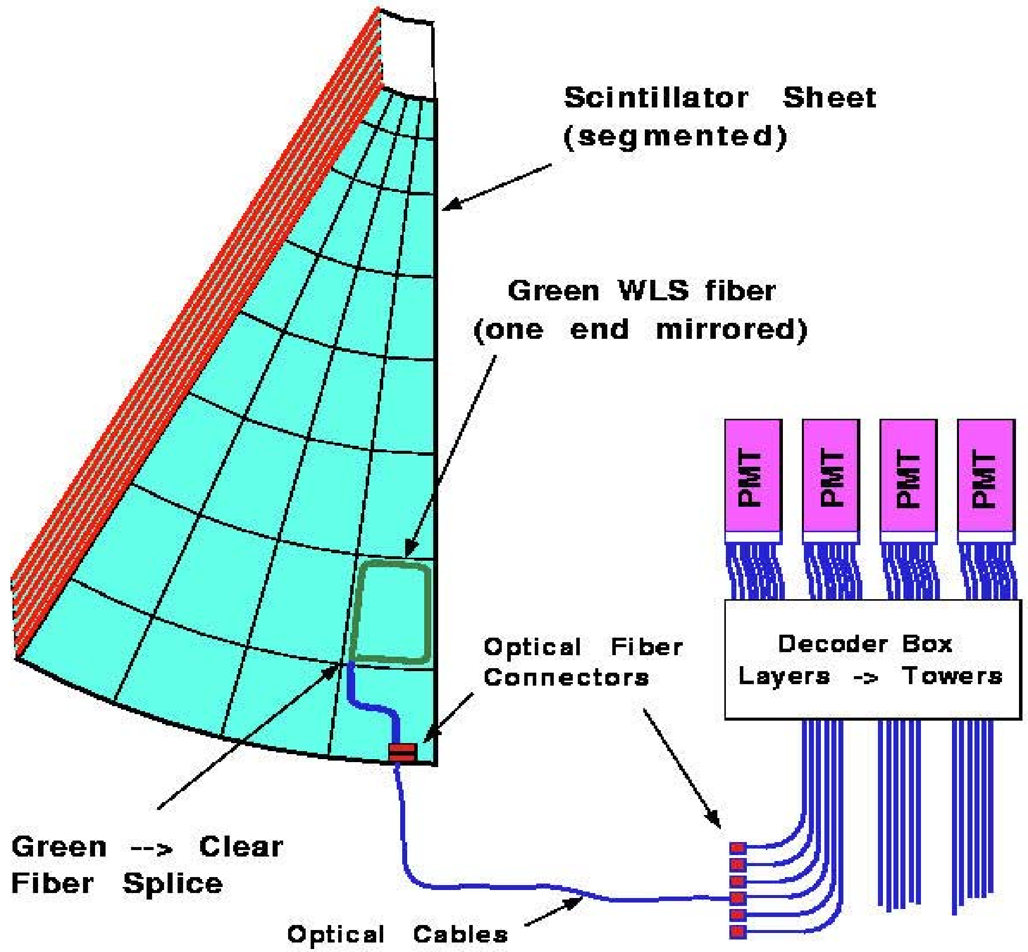


Overview of Endplug

Detector Elements: Scint. Tiles + WLS readout

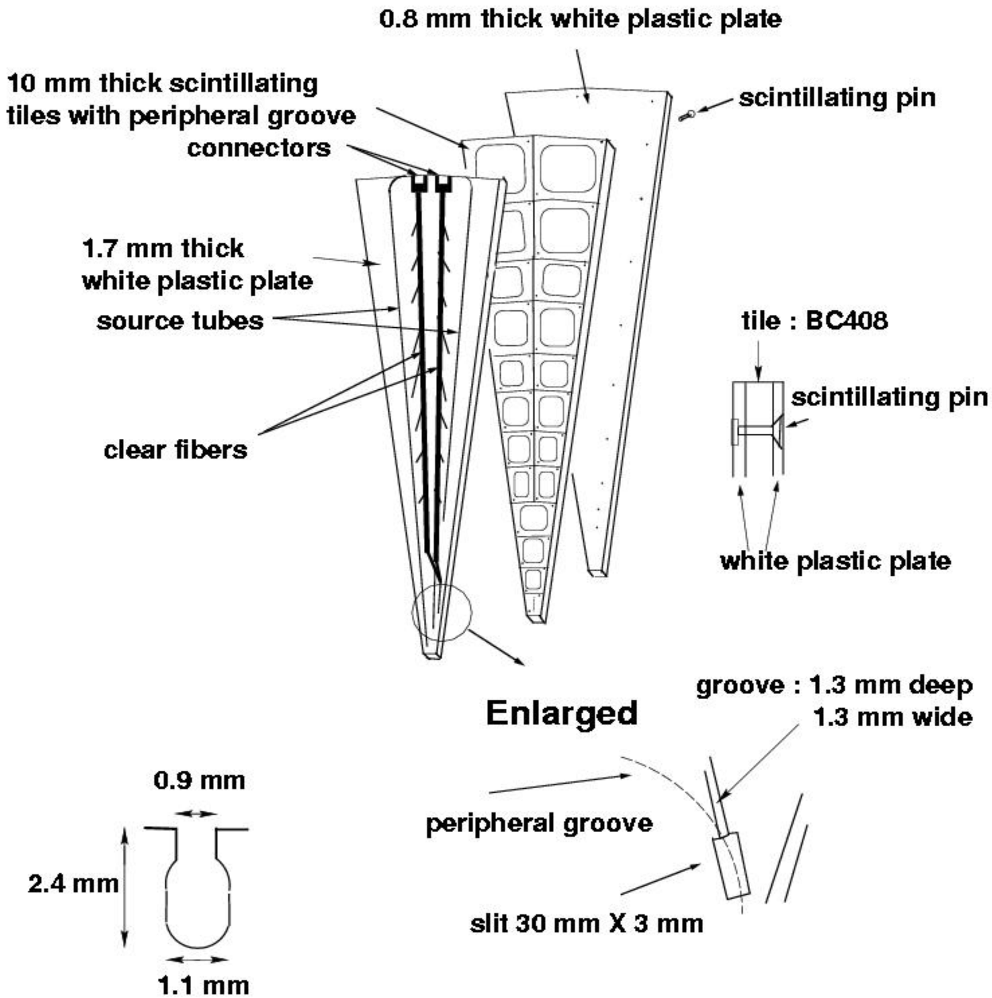
- **Plastic scintillating plates with optical fiber readout**
- **First large-scale implementation of tile-fiber technique**
- **References (CDF 5545):**

NIM A 247 (1986) 543
NIM A 256 (1987) 29
NIM A 340 (1994) 458
NIM A 352 (1995) 557
NIM A 360 (1995) 206
NIM A 420 (1999) 48
NIM A 452 (2000) 67



Responsible: Bologna, Brandeis, UCLA, FNAL, KEK, MSU, Purdue, Rochester, Rockefeller, Udine

Endplug Preshower



First layer of EM section read out separately

- MAPMT's are the same as used in the SMD (central shower maximum detector)
- 1 cm tiles
- Same tower structure as EM(960 channels)

Shower Maximum Detectors

- **Central: Gas chambers w/ strips and wires**
  - Important for electron, photon, pion identification
  - New FE electronics: SMQIE chip
  - <1% prob. channels, no aging
  - Upgrade CPR for Run 2b

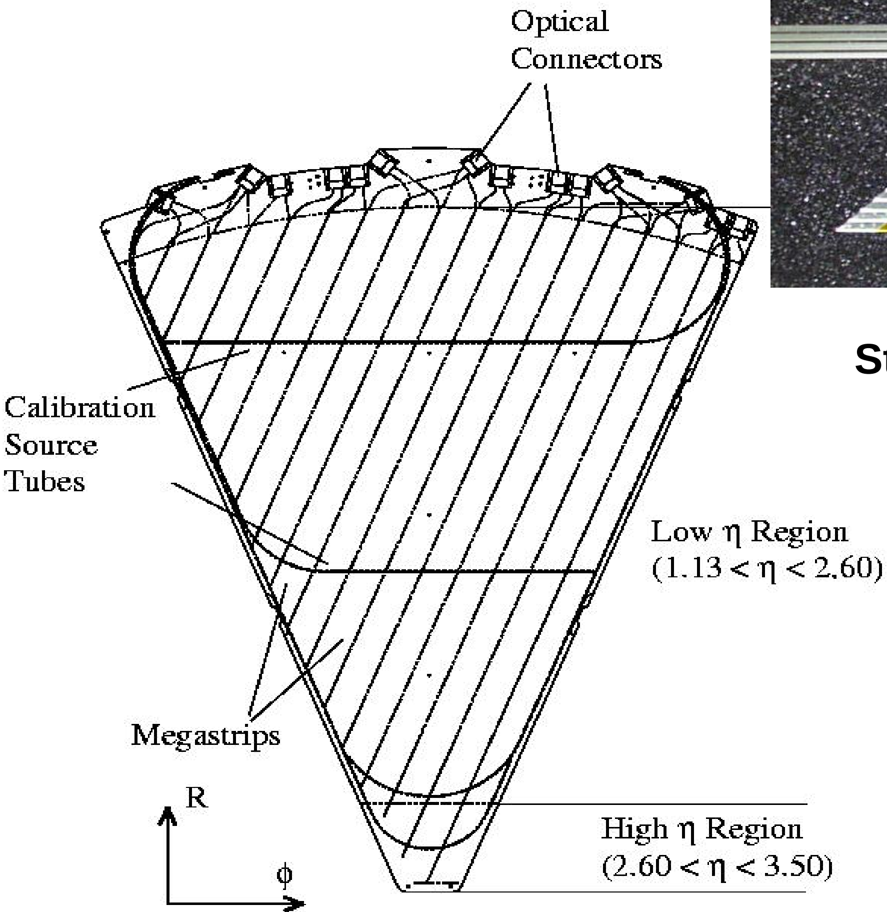
Luca's talk next

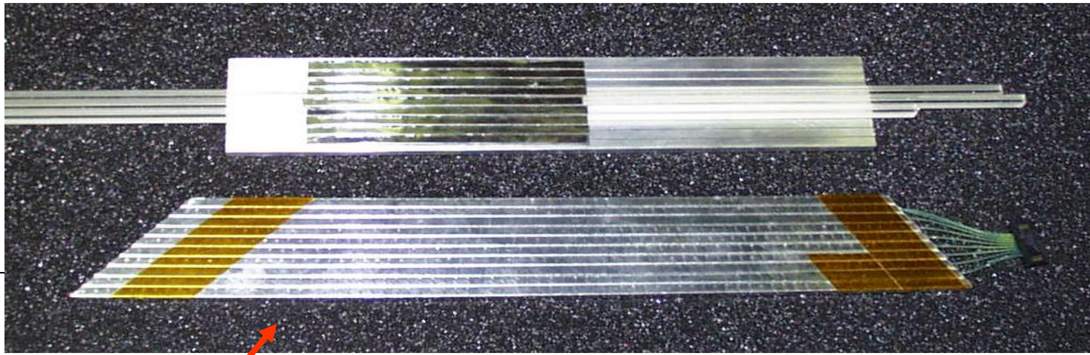
- **Plug PES/PPR new in Run 2**
  - Scintillating strip/WLS fiber
  - 2 layers ~6 rad lengths in
  - Energy in PES/PEM well-matched; position to 1.5 cm can improve with fwd silicon

Slide courtesy Mike Lindgren: DOE site visit 2000

Shower Maximum Detector Elements

- A position detector embedded at ~ 6 λ deep in the EM calorimeter measures the position of e's and γ's
- Sub-millimeter position resolution for energies > 100 Gev
- 6400 channels of 5mm strips





Strips

Words of Wisdom

Technology thought to be overall success. Nevertheless:

Some comments from the Endplug PES (shower max) experts on fibers and MA pmts (Thanks to Alon Attal, UCLA):

Wavelength-shifting fibers:

- **Kuraray Multi-Clad Y11-350ppm non-S-type, aluminized at far end (away from pmts)**
- **Chosen to maximize yield, no obvious problems**

Multi-Anode PMTs:

- **Hamamatsu R900-M16 phototubes. Problems with cross-talk introduced in implementation.**
- **Photocathodes compact, difficult to calibrate: Laser illuminates >1 pixel (tough for individual channels) & hard to "source" strips uniformly**
- **Dead Chs: replaced 15-20/470 pmts; 60 dead chs**
- **No obvious aging, but reduced gain at high eta**

Useful Contacts

Potentially useful contacts for WLS fiber and MA PMTs:

CDF Endplug and Central Shower Max/CPR:

- **Giorgio Appolinari (FNAL), Willis Sakumoto/Howard Budd(Rochester, based at FNAL), Steve Kuhlmann (ANL) , Karen Byrum (ANL), Jay Hauser (UCLA)**

CMS HCAL

- **tile-fiber with avalanche photo-diodes: Pawel de Barbaro**

Minerva

- **Tile-fiber w/ MA PMTs, like CDF CPR2 - Howard Budd (Rochester)**

Nova

- **WLS Fibers with Avalanche photodiodes - Ron Ray (FNAL)**

BTeV

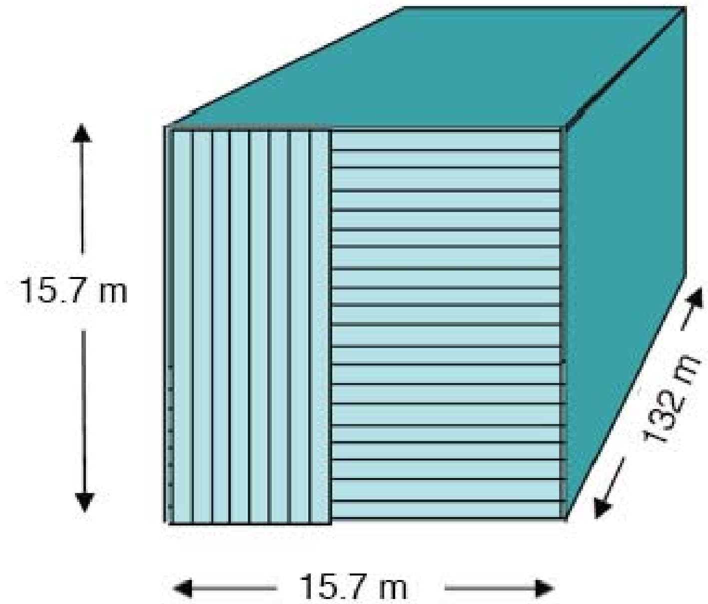
- **Rich Detector w/ MA PMTs - Marina Artuso (Syracuse)**

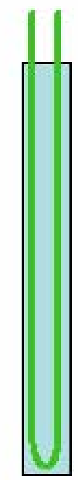
Veritas

- **Cerenkov telescope upgrade w/ MA PMTs - Karen Byrum (ANL)**

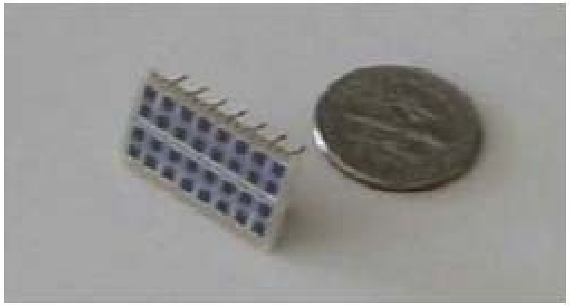
NOvA Far Detector

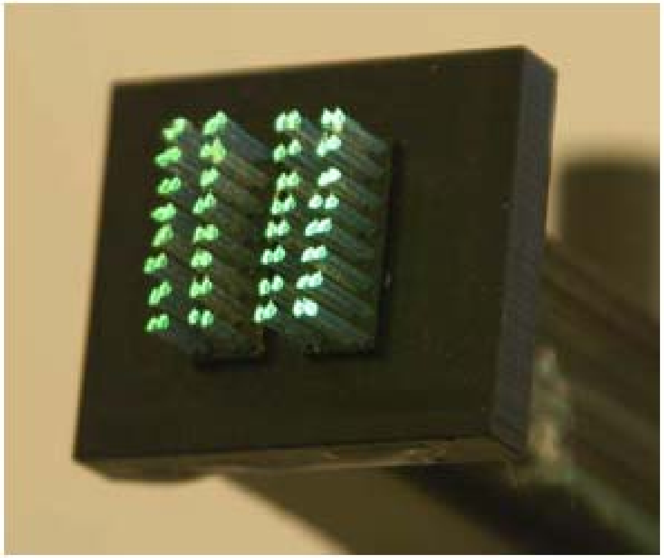
- 30 kT, low Z tracking calorimeter
- 80% active material (by weight).
- Optimized for detecting 2 GeV electrons.
- Rigid PVC extrusions filled with Liq. Scint.
- Add TiO_2 to PVC to maximize reflectivity.
  - Cell size of 3.87cm x 6.0 cm x 15.7 m
  - 32 cells/extrusion
  - 12 extrusions/plane
  - 1984 planes
  - = 23,808 extrusions
  - = 761,856 channels
- 0.8 mm looped WLS fiber into APD readout
- Fiber readout using Hamamatsu APDs



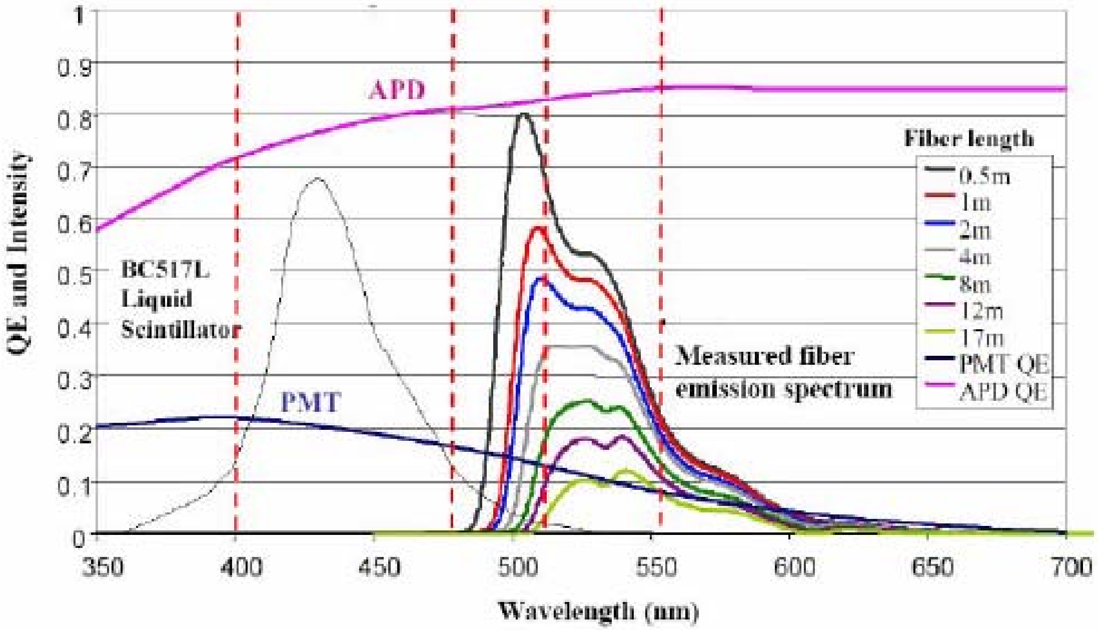


APDs





Advantages over PMTs:
- Quantum efficiency
- Cost - x4 smaller per channel than Multi-anode PMT
- High QE allows for very long modules, reducing channel count



Both ends of looped fiber go to the same pixel.
Two 0.8 mm diameter fibers fit comfortably on 1.8 mm x 1.05 mm pixel.

Summary

CDF has provided the proof-of-principle for tile/fiber technologies, and has gained some useful experience with multi-anode PMTs.

- **Endplug calorimeter technology ~decade old**
- **More recent practical experience with 2005 Central Pre-radiator (CPR) upgrade (see next talk)**
- **Other experiments are looking at these technologies and how they fit, given their implementation constraints**
- **Lots of current expertise on MA PMTs, (avalanche photo-diodes), and WLS fiber technology**